GENERAL ELECTRIC

Proposal for

CO-OPERATIVE 500-KV EHV DESIGN STUDIES

ELECTRIC UTILITY ENGINEERING

Proposal for

CO-OPERATIVE 500-KV DESIGN STUDIES

SCE

Southern California Edison Company

and

GENERAL ELECTRIC

September 25, 1962

Contents

Introduction

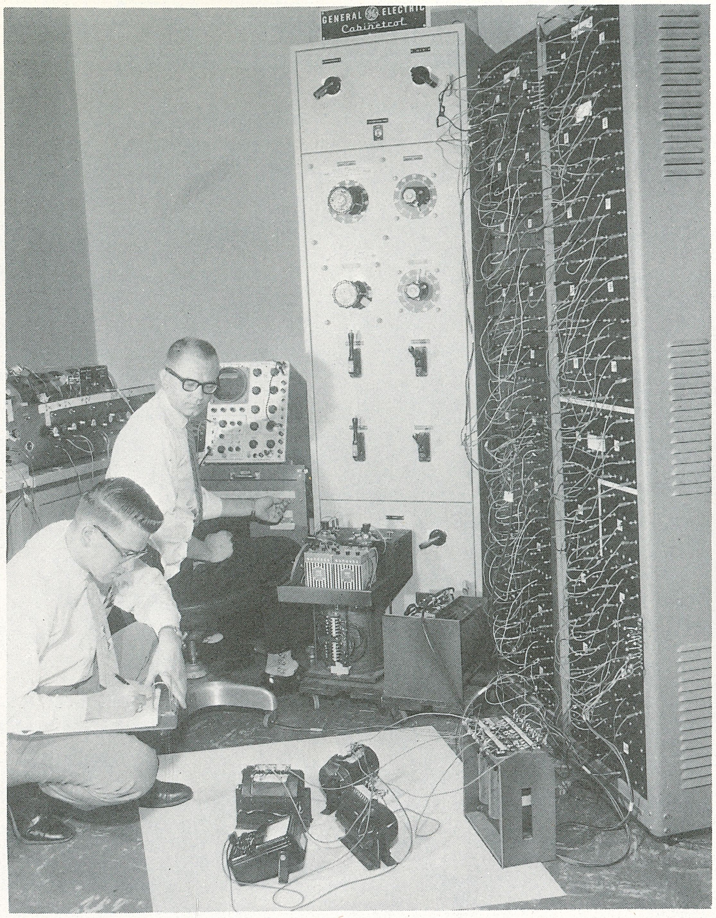
This proposal is presented in response to the Southern California Edison invitation to qualified organizations for engineering studies and development of design criteria for the Midway-Vincent 500 kv transmission line and terminal substations. It is an extension of a previous proposal, offered August 17, 1962, covering a suggested co-operative engineering program for the purpose of bringing to bear the full EHV capabilities existing in General Electric on the design of the 500 kv system.

This document is organized in sections in accordance with the format requested on page 2 of the Scope of Work document issued September 10, 1962, by Southern California Edison. Section I of this proposal is the response to the "Scope of Studies" outline on page 3 of the Edison Scope of Work document, and an appendix presents statements concerning "Design Criteria," "Equipment Recommendations," and "Testing."

September 25, 1962

SECTION 1

Summary of Areas of Investigation



Transient network analyzer determines system overvoltages.

A. Switching Surges

Nature of the Problem:
In any new EHV undertaking, the possibility of damage to equipment and interruption of service through overvoltages caused by switching operations must be analyzed. In many cases switching surges are effectively limited by arrester operation. From the standpoint of transformer protection the principal problem is one of defining the rating of the lightning arrester to be applied. This, in turn, determines the BIL which can safely be used.

The insulation system on EHV lines finds its limiting condition in switching surge strength. Modern philosophy on line insulation often results in switching surge strength considerably lower than the level that could be protected by presently available arresters. In this case it is important, from a line design standpoint, to assess the switching voltages produced by all realistic switching or light-load operating conditions.

Methods of Solution:
Switching transients may be very effectively studied on the transient network analyzer.

The transient analyzer is an analog computer on which the system to be studied is set up in miniature, accurately representing the characteristics of transformers, line, and circuit breakers as to saturation, magnetizing reactance, line reactance and charging

capacitance, variations in contact time of the three poles of a breaker, the effects of two-step closing, and other system and apparatus parameters. A unique feature of the transient analyzer is its ability to accurately represent the non-linear saturation characteristics of transformers.

Certain types of surge problems, notably those dealing with lightning arrester separation from protected apparatus and circuit breaker recovery voltage, are amenable to solution on a newly completed digital computer program. This program is in the process of extension to allow solution of a broader range of surge problems.

Objectives of Southern California Edison Studies:

The objectives of the proposed study may be broadly stated as the definition of overvoltage duty for which the Southern California Edison 500-kv system and its component apparatus must be designed. Emphasis will be on the initial 500-kv link, though the ultimate system will be represented by either complete modeling or a valid equivalent.

The transient network analyzer studies would consist of a review of pertinent literature, of recent PG&E studies on a very similar system, and of other similar studies, to confirm the relevance of their results, plus some specific extensions on the above studies. In particular, the objectives seen at present are:

1. Study switching surges on line energization, including the effect of two-step closing. The initial transient analyzer study would define maximum switching surge levels plus some approximate data on statistical distribution. A subsequent study may be required to define the statistical distribution more exactly.

2. Study of the possibility of transfer of surges from the 230-kv system with existing 230-kv breaker characteristics. Include the effects of multiple restrikes.

3. Confirmation that no-load conditions will be within tolerable bounds, including the effect of transformer saturation.

4. Define the lightning arrester location and performance required for the proposed system.

5. Study the advisability of furnishing tertiaries on the terminal 500-230 kv transformers.

6. Examine other surge conditions or apparatus duty suggested by the above studies.

Interrelation with Other Studies:

The transient voltage study is scheduled first on the agenda since it affords the following:

1. A basis of defining performance requirements and locations for lightning arresters, apparatus BIL's, use of tertiaries, the optimum size and the location of shunt reactors.

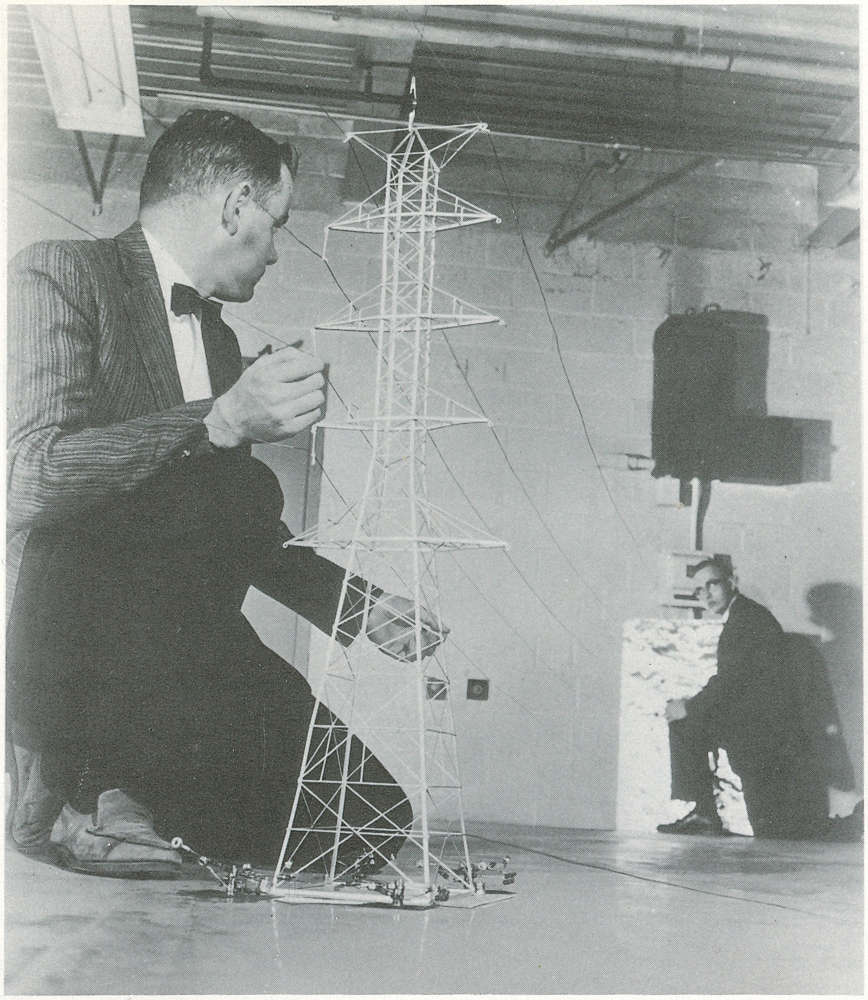
2. Provide data for the electrical design of towers. Switching surge studies plus some existing tower design data will permit a "trial design" for full-scale tests.

3. Statistical insulation planning studies can proceed with statistical switching surge data afforded by transient analyzer studies. Initial statistical approximations will permit a clearer definition of the problem and will point out which distributions required more exact study.

Timing:

The initial transient network analyzer study can be scheduled for November, 1962. This would be approximately a two-week study with the expectation that another such study would be scheduled early in 1963 to pursue in greater detail problems felt most critical after initial studies.

Digital transient studies on single-phase equivalents will be available at any time on short notice. The three-phase digital program will be completed early in 1963, permitting additional studies at that time.



Model tower transient response is used to assure good lightning performance.

B. Lightning Performance

Nature of the Problem:

An unusually high outage rate experienced on some recent 345 kv lines has given rise to renewed efforts at predicting the lightning performance of lines in the design stage. As a result of theoretical investigation into this problem, a calculation technique has been developed and applied to a number of new line designs.

Methods of Solution:

In the first phase of calculation, 50:1 miniature towers are constructed representing each of the major tower design alternatives. These towers, with conductors installed, represent the line, which is subjected to simulated lightning strokes to the ground wires at various points along the span and at the tower. Measurement of the voltages produced across the insulators give complete information as to the response of the line to lightning strokes.

Phase two of the calculation combines the results of Phase one and supplementary shielding failure data and then performs a Monte Carlo calculation to

duplicate 10 to 30 years of thunderstorm experience, using lightning data applicable to the system under study.

The results of this calculation show total outages per year as a function of:

1. Isokeraunic level
2. Basic line design
3. Number of ground wires
4. Median footing resistance
5. Footing resistance distribution

Objectives of Southern California Edison Study:

Specific objectives of the Southern California Edison study would be to determine whether satisfactory lightning outage performance could be achieved without the use of two overhead ground wires and to establish the relative importance of footing resistance in the performance of each alternative.

Interrelation with Other Studies:

Lightning outage calculations are not sensitive to the final design details of the structures being studies. This aspect of the tower design can be investigated as soon as the general tower type is known.

Timing:

The lightning performance calculation would probably be done in the Spring of 1963 or as soon as the general tower design is selected. In the meantime, data on footing resistance along the right-of-way might be sought for use in performance calculations.

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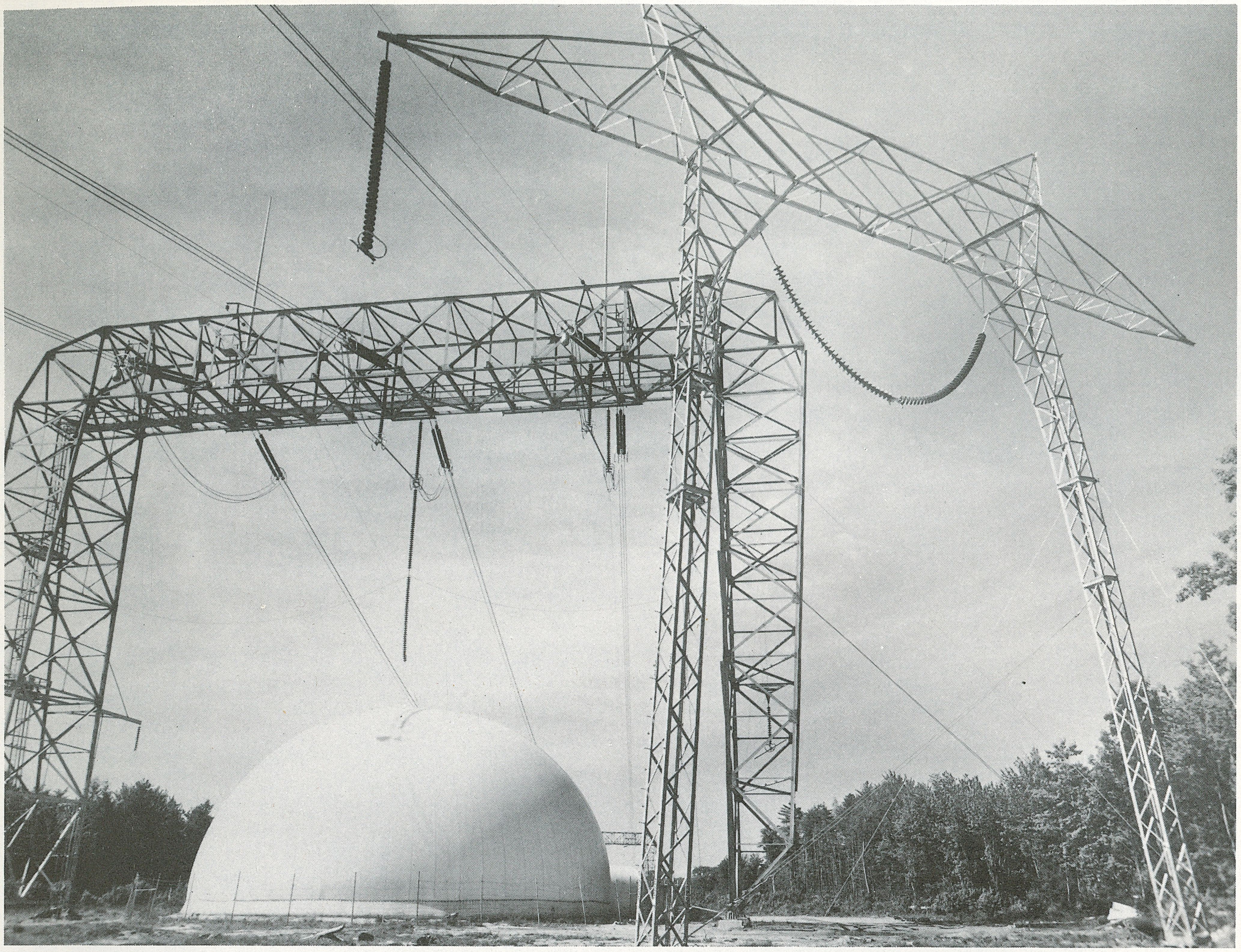


Full-scale tower, subjected to flashover tests, guides ultimate tower design.

C. Insulation

ELECTRICAL DESIGN OF TOWERS

Nature of the Problem

Recent investigations on Project EHV have shown a serious discrepancy between flashover values measured on long insulator strings in the laboratory as compared with results measured on the same string when installed on a tower. It has been shown that tests on EHV insulator strings should be made in place, on the tower with which they are planned for use.

In addition to the detrimental effect of tower proximity in the strength of suspension insulator assemblies, some of the correction factors applying to ambient conditions have been found to differ from those traditionally used.

Methods of Solution

Although some very general relationships have evolved from prior work in this area, the present state of the art suggests that designs be tested full-scale and adjusted during the test program to assure adequate total strength and co-ordination between insulator strength and the strength of air gaps be-

tween the tower and the phase conductors. Successful design studies of this sort have been performed.

By the winter of 1962-63 it is likely that a relatively good basis for preliminary design for the Southern California Edison towers will be obtained. In the spring of 1963 an actual prototype can be tested for electrical strength tests.

Objectives of Southern California Edison Studies:

Preliminary work will consist of evaluating the electrical strength requirements of the Southern California Edison towers and reviewing tests performed for PG&E and others as a basis for arriving at a preliminary tower design. This tower will then be erected at Project EHV and tested for switching surge strength in fair weather and during rain, with the 3000 kv impulse generator located at Project EHV.

Interrelation with Other Studies:

The wet switching surge withstand strength requirements of the tower insulation will be determined, in part, from transient network analyzer tests which simulate switching conditions on the future system. Statistical insulation planning studies will supplement transient analyzer tests by evaluating all of the pertinent statistical variables to forecast the total outage performance of alternative levels of line insulation strength.

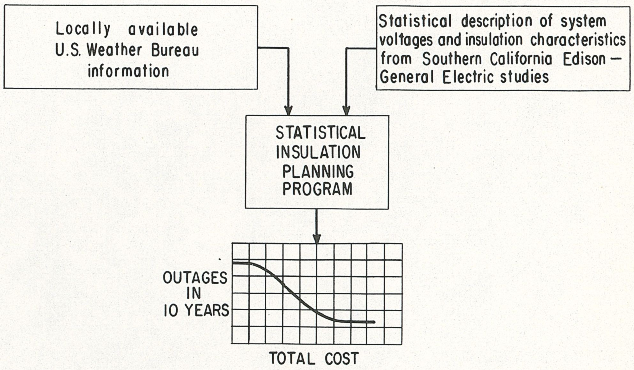
Timing:

Study of preliminary tower design ideas should begin immediately following the first transient network analyzer test program and extend through the winter of 1962-63. These studies will be based on PG&E tests and all similar tests performed subsequently.

STATISTICAL INSULATION PLANNING

Nature of the Problem:

Traditional methods of designing and specifying the insulation of transmission lines and terminal apparatus have been based on the maximum electrical stress anticipated in service. This philosophy continues to be justified in those cases where insulation failure may be considered catastrophic, e.g., transformer insulation. On some portions of the system insulation system, notably on the transmission line, insulation failure is not at all catastrophic and may therefore be interpreted with statistical methods. Rather than designing for maxima, it is advantageous to consider each variable in its true statistical nature (wind velocity, precipitation, switching surge magnitude, etc.) and combine them so as to yield an over-all outage rate for various design alternatives.



Statistical analyses optimize insulation investment.

Methods of Solution:

A digital computer program has been completed which takes each of the statistical variables affecting a problem and, considering the cross-restraints these variables place on one another, predicts the total performance history of the composite system in terms of

failures per year. The combined solution can include a number of insulation subsystems, e.g., the center phase insulation of a line, the outside phase insulation of a line, bus insulation, apparatus insulation, etc. The program is supplemented by an auxiliary program which relates the anticipated weather history in the geographic area of concern to the problem being studied. In the case of the insulation planning studies, a composite statistical frequency of insulation withstand strength would be developed by the auxiliary program for each of the insulation subsystems being studied.

Objectives of Southern California Edison Studies:

Both the scope of these studies and the nature of the cost information used in them would have to be the subject of cooperative discussions between Southern California Edison and the General Electric Company. The initial studies would include the insulation systems (center phase and outer phase) of the transmission line plus several items of station insulation and/or apparatus. The primary objective of this program would be to appraise the electrical design of the Southern California Edison 500-kv line and station insulation systems to find the most economical design that is acceptable from an outage standpoint, with full evaluation of all of the statistical factors involved.

Interrelation with Other Studies:

This work would be closely related to the full-scale testing of the Southern California Edison 500-kv towers inasmuch as the insulation strength of these towers would be a major input to the program. The frequency distribution of switching surges would also be an important input to the statistical planning study. Preliminary estimates of both of the foregoing variables would be sufficient for preliminary studies that would serve to clarify the importance of each of the input quantities and establish some preliminary estimates of the design optimums.

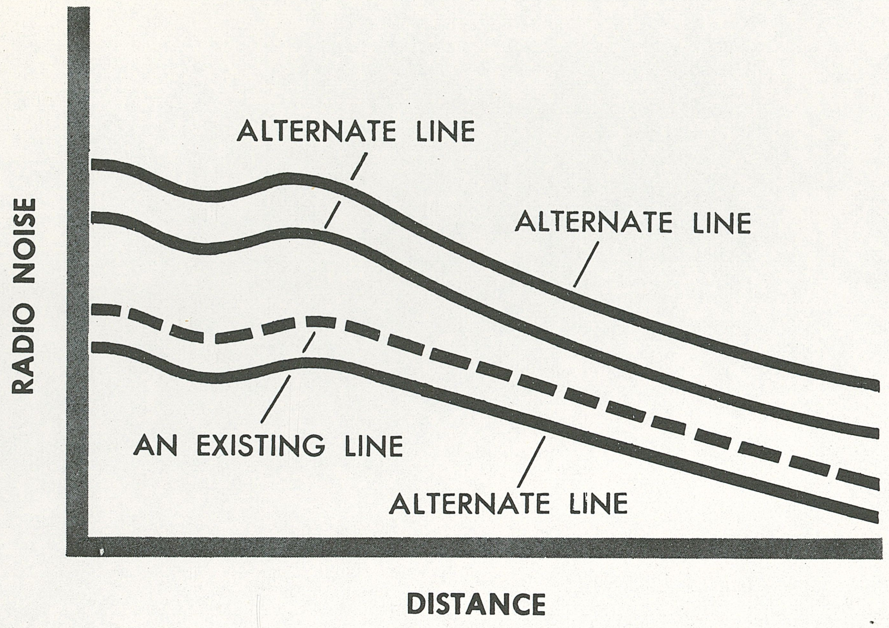
Timing:

Because of the original nature of this work, it should be a continuous program of study over the planning stage of the 500-kv system. Three phases of study are suggested below:

Phase 1. (November 1962) Agree on the scope of insulation to be included, the range of statistical variables to be included, and the source of statistical data.

Phase 2. (On completion of the first transient network analyzer tests and accumulation of other input data.) Perform calculations for a number of reasonable insulation design alternatives.

Phase 3. Refine the calculations for the final design alternatives, using the most accurate input attainable.



Radio noise levels can be controlled by line design.

D. Radio Noise

Nature of the Problem:

The need for careful prior evaluation of radio noise levels has increased in importance with each upward step in voltage levels. At 500 kv it becomes extremely important to predict in advance the radio interference characteristics of proposed designs as they are affected by:

1. Conductor diameter
2. Conductor surface condition
3. Altitude
4. Voltage
5. Ground wire
6. Phase spacing
7. Weather
8. Radio signal strengths on the proposed right-of-way

Methods of Solution:

Research in the theory of radio noise has been under intensive investigation in the General Electric Company since an early paper on this subject was published by Gayle Adams in 1955. The work of Dr. Adams, together with other theoretical contributions and new relationships found in Project EHV, have been incorporated into a digital computer program to predict radio interference levels of alternative line designs.

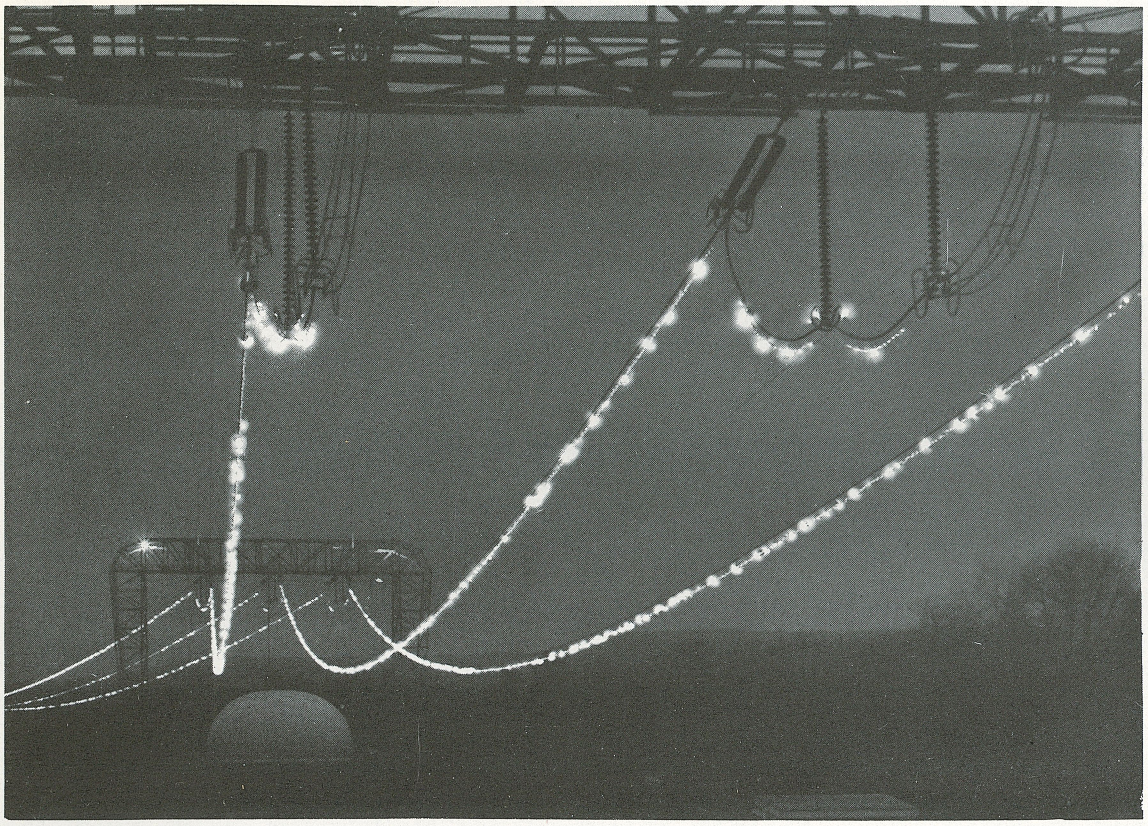
The computer output is in the form of lateral profiles of noise (in microvolts per meter) extending from the center of the right-of-way to a point 200 feet laterally. In most design studies, a number of design alternatives are calculated for comparison with calcula-

tions of existing lines, known to be satisfactory from a radio noise standpoint. Using data from a survey of signal strengths on the right-of-way, one can assess alternate designs in terms of the quality of radio reception they will afford. In addition to the general noise characteristic of a given design, information is furnished which shows how far the effect of local sources extend their influence by propagation along the line.

Objectives of Southern California Edison Studies:
The results of the PG&E study would be critically reviewed for applicability to the Southern California Edison line. Calculations would then be extended to give lateral noise profiles of three and four conductor bundles. In general, the objects would be to determine the noise performance of particular conductor configurations and, for a given noise level, to determine the size of the subconductor necessary in two, three, and four conductor bundle alternatives. All of the foregoing bundle alternatives would be appraised for both fair and foul weather performance.

Interrelation with Other Studies:
Related to economic choice of conductor as stated therein. This solution also has a bearing on conductor stringing practice, right-of-way width requirements, and in some cases, right-of-way routing.

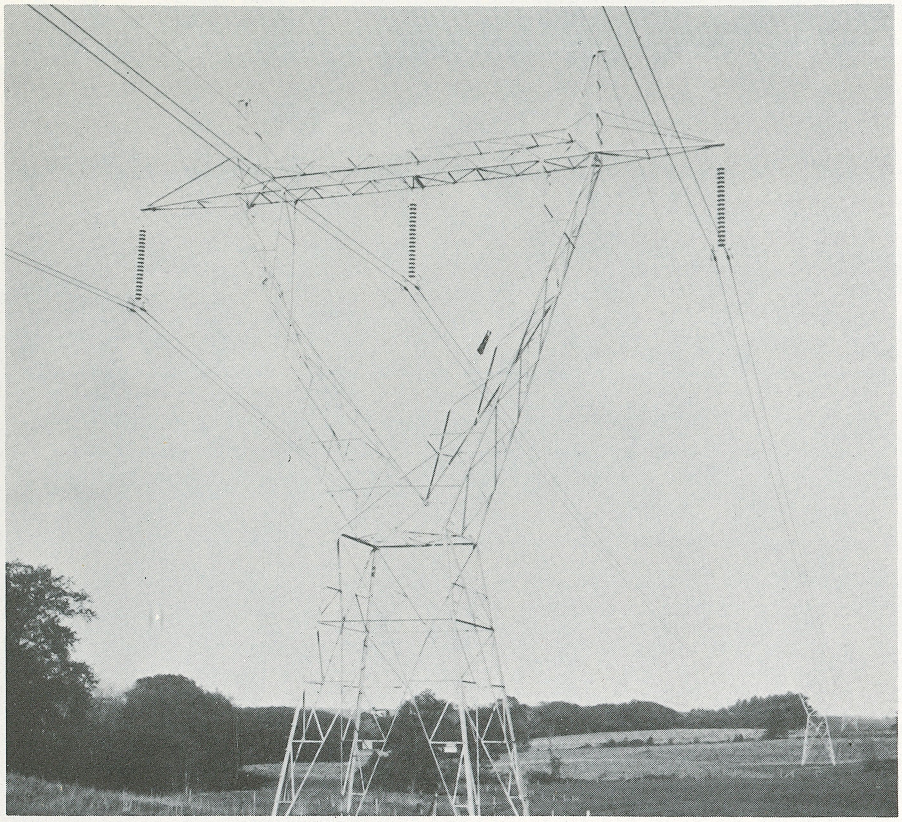
Timing:
The radio interference studies can proceed at any time after an approximate configuration is known. Preliminary cases could be run concurrently with economic conductor size studies. Other cases might be suggested when the final conductor choice is made.



Corona loss is a factor in the determination of optimum conductor size.

E. Corona

From Project EHV data and computer calculations, fair and foul weather corona loss levels for a variety of conductor alternatives will be established. These will be for ultimate use in conductor economic studies as described in sub-section F.



Optimum conductor diameter is determined by digital computer studies.

F. Economic Conductor Size

Nature of the Problem:

The significance of corona losses in foul weather increases markedly above 230 kv. For practical 500 kv designs, foul weather losses may exceed 20 megawatts per 100 miles of single circuit line. Since corona loss of this magnitude may coincide with peak system load in some cases, and therefore incur a demand charge, it should be considered along with traditional factors in the selection of the most economical conductor.

Methods of Solution:

Through research into corona loss theory, coupled with loss data obtained on Project EHV, it is possible to predict foul weather corona loss for a wide variety of conductor choices and weather conditions. A computer program has been written which solves for the optimum conductor size of a given line, including consideration of:

1. Conductor configuration
2. Foul weather corona loss levels and their coincidence with peak system load
3. I^2R losses
4. Line loading characteristics
5. Line length
6. Changes in tower costs as conductor size changes
7. Energy costs, demand charges, RKVA charges, etc.
8. Series compensation and/or shunt reactance

The results of this program show annual cost differential versus conductor area for pertinent assumptions in the above areas.

Objectives of Southern California Edison Studies:

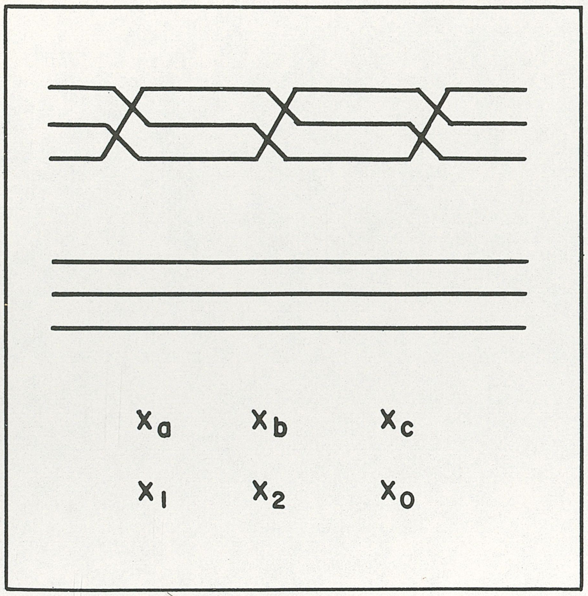
Upon agreement as to those economic factors that are relevant in Southern California Edison's case, the applicability of PG&E cases would be critically reviewed. Additional computer runs would then be made to extend the results to three and four conductor bundles and determine the optimum diameter for the subconductors in each case.

Interrelation with Other Studies:

The economic choice of conductors is closely related to the diameter requirement imposed by radio interference. Should the diameter suggested by economic concerns be smaller than that suggested by radio interference studies, the economic question would be reopened to determine the most economic means of achieving the diameter dictated by radio noise, i. e., by expansion with conducting or non-conducting material, or by an increased number of smaller conductors in the bundle.

Timing:

These studies can be performed at any time convenient to Southern California Edison. They can also be done concurrent with some of the radio noise studies.



Impedance matrixes and effects of untransposed conductors are determined with a computer program

G. Conductor Transportation

Nature of the Problem:

While it has been generally accepted practice on single circuit EHV lines to omit transpositions, a comprehensive evaluation of the effects of the resulting unbalance is worthwhile from at least two standpoints: (1) Demonstration of the exact extent of negative and zero sequence currents under normal load and under fault conditions for use in possible public utility commission relations, and (2) Establishment of the magnitude of parasitic losses resulting from unbalanced currents to assure that the capitalized cost of said losses are less than the cost of transposing.

Methods of Solution:

A digital computer solution has been developed which evaluates the effects of electromagnetic and electrostatic unbalance due to the omission of transpositions. In the process, the program produces accurately the complete impedance matrix, both in phase quantities and symmetrical component quantities. The program can be used for all system lines, and includes the effects of inter-circuit mutual coupling.

Objectives of Southern California Edison Studies:

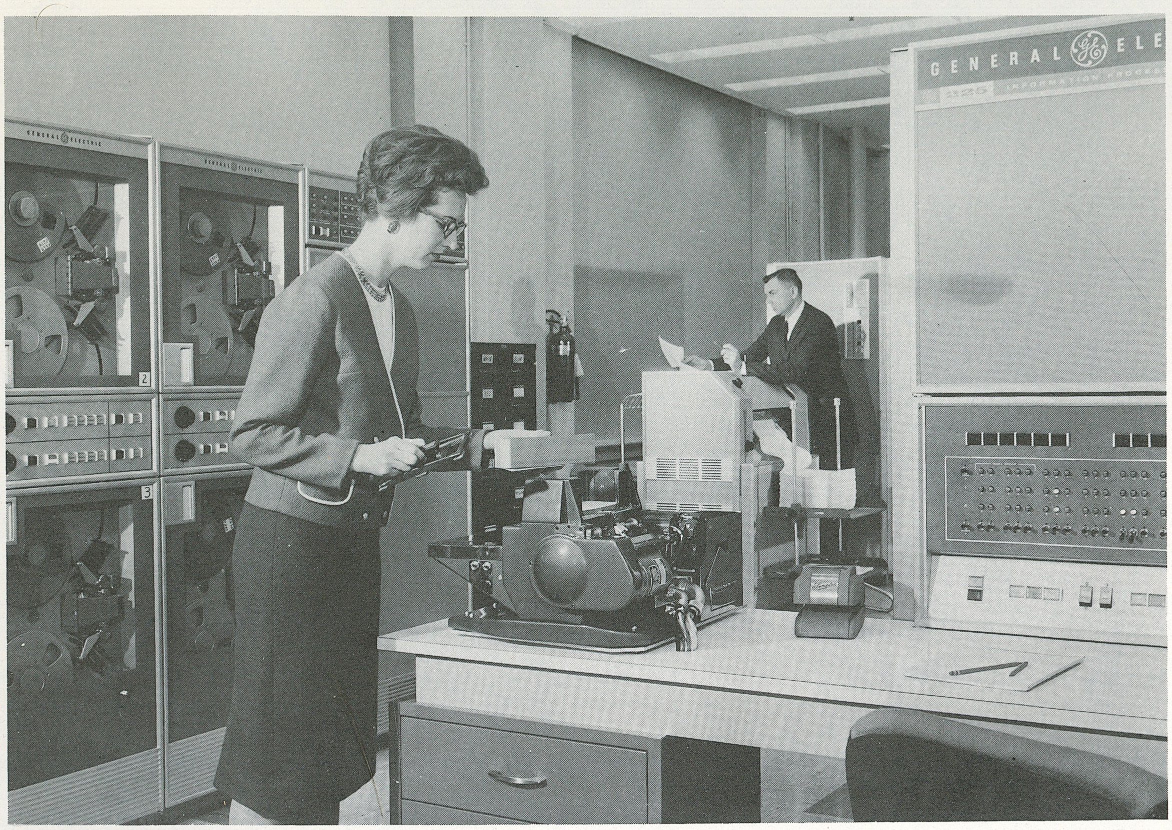
The major objective is the establishment of the percent zero and negative sequence currents under normal load and under short circuit without the transposition of conductors, including the effect of balanced terminal impedances. A second objective is the calculation of the complete impedance matrix for the 500 kv line for use in load flow studies, transient analyzer studies, and short circuit studies. The program is available for use on transmission circuits of any voltage.

Interrelation with Other Studies:

While exact line constants are relevant to the transient analyzer study, stability studies, etc., they need not precede these studies, since other constants (transformer reactances, reactor ratings, etc.) have such prominent effects. The execution of the transposition study is dependent on the determination of the final conductor configuration, as determined from the radio noise, insulation, and lightning studies.

Timing:

The transposition study is presently scheduled for the latter part of the complete EHV study program. However, if it is determined that earlier solutions, even if approximate, are desirable, preliminary computer runs will be made, followed by final runs after conductor configuration has been established.



Digital computers add powerful leverage in all ehv system design studies.

H. Other Design Studies

While the foregoing sections list some prominent problem areas of EHV system design and their methods of solution, it is the purpose of this proposal to make available any other EHV information that will prove useful to Southern California Edison. Some specific areas of additional interest are:

1. Analytical studies and laboratory tests relative to the elimination of fast rates of rise on waves entering 500 kv switching stations.

2. Analytical studies and laboratory tests relating to the suppression or localization of radio interference.

3. Analytical studies using matrix methods for the solution of radio frequency signals on overhead phase conductors or insulated ground wires.

SECTION 2

Technical Information and Assistance to Be Supplied by Southern California Edison

Technical Information and Assistance to be Supplied by Southern California Edison

The listing of specific information herein follows the order given on pages 3 and 4 of the Edison Scope of Work document. Input information to be obtained during the course of the program is not listed. It is expected, with the close lines of communication that will exist between Edison and General Electric engineers, that details not specified will be easily obtained.

Technical Information:

A. Switching Surge Study

1. System diagrams showing interconnection of 500 kv line with existing 230 kv system, and ratings of major apparatus.
2. Line reactances, susceptances, etc., for major 230 kv lines.
3. Existing major transformer reactances.
4. Machine reactances.
5. Short-circuit impedances and approximate X_0/X_1 ratios at all major 230 kv busses.
6. Preferences or approximate specifications for 500 kv transformer reactances. (These will be part of the conclusions and recommendations of the study; however, it would be useful to have the benefit of the thinking of Edison's engineers relative to these quantities.)

B. Lightning Performance Study

1. Approximate tower design.
2. Approximate statistical distribution of tower footing resistances.
3. Isokeraunic level and its variation over the right-of-way.
4. Altitude profile of right-of-way.

C. Insulation Study

1. Local weather statistics.
2. Altitude profile of right-of-way.
3. Approximate tower design.

D. Radio Noise Study

1. Local weather statistics.
2. Radio signal strengths over the right-of-way. (Assistance in a survey can be provided, as described elsewhere.)
3. Basic line and conductor configuration. (This is partly dependent on the outcome of other studies in the program; however, a "reference" configuration would be helpful in planning the radio noise study.)

E. Corona Study

No data required from Edison.

F. Economic Conductor Size Study

1. Local weather statistics.
2. Estimated load levels and load factors.

3. Estimated probability of coincidence of foul weather with system peak load.

4. Energy and capacity charges applicable to corona loss.

5. Fixed charge rate for line investment.

G. Transposition Study

All the inputs for this study are produced in other studies in the program. If preliminary answers are required, the "reference" configuration of "D. Radio Noise Study" above is needed.

H. Other Studies

To be specified if and when needed.

Technical Assistance:

To assist in this program, capable engineering manpower, represented by two or more Edison engineers, to work in Schenectady, New York, and/or Pittsfield, Mass., should be assigned. These people will be expected to contribute in laboratory work and calculations, guided by General Electric engineers assigned to the project. They will furnish appropriate cost data applying to the Edison system and will assist in arriving at sound conclusions and recommendations from the results of the tests, and in writing the reports.

In general, two men should be assigned at any one time – approximately during the periods as shown by the schedule given in Section 4. It is not necessary that these men be located in Schenectady or Pittsfield during the full time of the study. The planning and analyzing work will take place at Edison's offices in Los Angeles as well as at General Electric facilities.

Equipment:

To execute the Insulation Study, a full-scale prototype tower is needed. It is expected that Edison would design, furnish, and erect such a tower, as described in Section 1, Part C, at Project EHV, in Pittsfield, Mass. Preliminary design would be based on the switching surge ratio, as determined from the initial switching surge study, and on Edison's experience at 230 kv, combined with applicable results of tests made on the PG&E 500 kv tower and data available from tests currently in progress on waist-type towers. General Electric will provide these latter test data.

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SECTION 3

Resume of Key General Electric Personnel

Resume of Key General Electric Personnel

General Electric's contribution to the co-operative studies will be performed by the Systems and Analytical components of Electric Utility Engineering Operation, located in Schenectady, New York, and at Project EHV in Pittsfield, Mass. These groups, totalling approximately 75 professional technical people, have had many years of application engineering experience in all phases of electric utility engineering, backed up by the most modern and efficient analytical facilities and techniques. In addition, they have at their disposal the facilities and engineering manpower of the High Voltage Laboratory at Pittsfield, the Switchgear Development Laboratory at Philadelphia, and the Insulator Laboratory at Baltimore. AEP NOTE

Individuals within Electric Utility Engineering Operation who will be actively participating in the co-operative study are listed below:

J. F. Young - General Manager, Electric Utility Engineering Operation

P. H. Light - Manager, Electric Utility Analytical Engineering

W. J. McLachlan - Manager, Electric Utility Systems Engineering

L. O. Barthold - Technical Director, Project EHV

Mr. Barthold will be Project Co-ordinator for the joint Edison-General Electric endeavor, and will spend essentially all of his time on the project, once it has begun to move. He has had extensive experience in all the problem areas to be considered, and will be responsible for the successful conclusion of each phase of study. The team of General Electric people assigned to this project are listed as follows, according to the particular area in which they will work:

Switching Surges:
- I. B. Johnson
- D. E. Hedman
- D. D. Wilson
- J. W. Yetter

Lightning Performance:
- J. G. Anderson
- F. A. Fisher

Insulation:
- J. G. Anderson
- A. F. Rohlfs
- D. D. Wilson
- J. W. Yetter

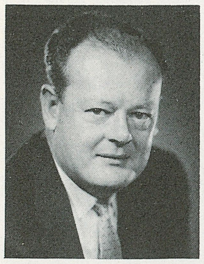
Radio Noise:
- M. H. Hesse
- J. J. LaForest

Corona:
- C. B. Lindh

Conductor Choice:
- J. J. LaForest
- C. B. Lindh
- H. O. Simmons

Transposition and Line Constants:
- M. H. Hesse

Engineering Co-ordination between Edison and GE:
- W. S. Moody
- R. B. Kimball



JAMES F. YOUNG

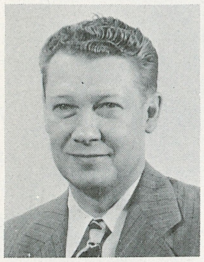
General Manager
Electric Utility Engineering Operation

He joined G. E. shortly after his graduation from Lafayette College in 1937, where he received a BSME degree magna cum laude and with honors. During his 25 years with General Electric Mr. Young has held executive positions in several different branches of the Company. Early in his career he supervised engineering training courses and later, during World War II, he was engineer for rocket launchers and torpedo gyroscopes. After the War he assumed managerial positions in the Consumers Goods component of the Company.

In the early 50's Mr. Young was assigned to Engineering Services, where he had the broad responsibility of appraising technical work throughout the Company with particular attention to energy conversion activity. His investigations of unconventional combinations of energy sources and electrical energy conversion processes have contributed greatly to the body of knowledge of this subject.

Later he was named manager of the General Engineering Laboratory, guiding development work which reached into almost every area of applied science. As General Manager of Electric Utility Engineering, he has responsibility for directing the Company's efforts in developing advanced concepts and techniques for application to electric utility systems.

Mr. Young is a member of Tau Beta Pi, Phi Beta Kappa, the National Society of Professional Engineers, and a number of societies including AAAS, AMA, AIEE, CIGRE, and ASME. He is active in several committees and professional divisions of ASME, and the Materials Advisory Board of the National Research Council. He edited the first edition of "Materials and Processes," (1944) and is the author of the second edition of this volume (1954). He has also written numerous articles for technical journals. The holder of 20 patents, his name first appeared in "Who's Who in Engineering" in 1953.



PHILIP H. LIGHT

Manager
Electric Utility Analytical Engineering

Mr. Light attended Iowa State University and received a BS degree in electrical engineering in 1935. He joined General Electric that year on the engineering test program. In 1937 he was assigned to the Central Station Engineering Division, to study system overvoltages, their cause and means of control, and for six months in 1939 was an exchange engineer with the Georgia Power Company. When he returned to General Electric in Schenectady he specialized in application of system protection equipment.

In 1946 Mr. Light was made a Sponsor Engineer in the Electric Utility Section with responsibility for application of General Electric apparatus to utility systems on the West Coast. Subsequently, he held several managerial positions in the Company's Electric Utility Engineering component and was appointed to his present position in 1960.

Mr. Light is a member of Tau Beta Pi, Eta Kappa Nu, and Phi Kappa Phi fraternities and a Fellow of AIEE. He has presented numerous technical papers and talks at district and national AIEE gatherings, has served on the National Program Committee, and since 1958 has been a member of the District Planning Committee, Empire District. A registered professional engineer in New York State, he holds seven patents for transmission line protective equipment.

WILLARD J. McLACHLAN

Manager
Electric Utility Systems Engineering

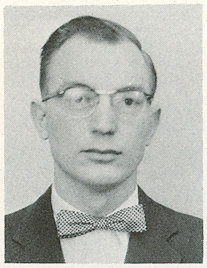
Mr. McLachlan's association with the electric utility industry dates back to the 20's, when he took part in the early development of a-c secondary and primary network systems. Over the years his many contributions to systems development have won wide recognition -- including the General Electric Charles A. Coffin Award, the Company's highest honor, for his part in the development of a new design network protector.

His service with General Electric began in 1924, the year he was graduated from Washington State College with a BSEE. After a year in the Testing Department he joined the Relay Engineering Section of the Switchboard Department, where he did pioneering work on automatic station and secondary network relays. In 1927 he transferred to Central Station Engineering, and worked closely with electric utility companies in innovating solutions to distribution system problems.

He has held managerial positions in G. E. since 1939, when he was appointed manager of the Product Division, Central Station Engineering. He later became manager of the Central Station Engineering Division, in charge of company-wide application engineering operations with the electric utility industry. He subsequently served as manager of Engineering Planning and Development and Electric Utility Engineering in the User Industries Sales Department.

In his present position Mr. McLachlan directs the Company's application engineering activities in the fields of power generation, transmission and distribution, and system automation.

He is a member of Phi Kappa Phi, Tau Beta Pi, and Sigma Tau honorary fraternities, of the New York Society for Professional Engineers, and of AIEE and NEMA. A Fellow in AIEE, he has served on several committees, including the Switchgear Committee, the Circuit Breaker Subcommittee, and the Power Division Coordinating Committee.



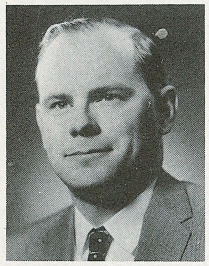
LIONEL O. BARTHOLD

Technical Director - Project EHV
Electric Utility Systems Engineering

A graduate of Northwestern University with a BS in physics, Mr. Barthold has been with General Electric since 1952, and with Electric Utility Engineering since 1954.

He is presently in charge of the technical program of study for Project EHV and is chairman of General Electric's EHV Planning Council. His principal engineering responsibilities are concerned with radio noise and R.F. propagation studies, arc-deionization and high-speed reclosing, power system transients and dynamic overvoltages, and the overall electrical design of transmission systems.

He is a member of AIEE, of CIGRE, and of the New York State Society of Professional Engineers. He has contributed numerous papers to the technical press, two of which have won first prize in the Power Division of AIEE.



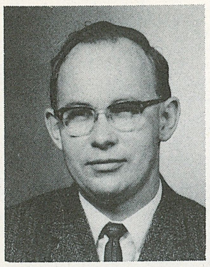
JOHN G. ANDERSON

Research Engineer - System Insulation
Project EHV

Upon graduation from Virginia Polytechnic Institute with a Bachelor of Science degree in electrical engineering, Mr. Anderson entered military service. While in the service he served as Communications and Radar Officer in the South Pacific theater.

In 1946, he joined General Electric Company on the engineering test program with assignments in the Power Transformer Department and the Pittsfield Works Laboratory. The first major engineering assignment was that of conducting the Empire State Building lightning investigations from 1947 to 1949. Subsequently, his efforts were directed toward research and development activity on high voltage insulation problems and lightning effects. During this period Mr. Anderson developed the Monte Carlo method of predicting transmission line outages and also invented the Teinograph, General Electric's line shielding failure indicator. Another significant accomplishment was the conception and direction of the development of nanosecond models for determination of transmission line performance.

He has authored or co-authored over 20 AIEE transaction papers dealing with the subjects of lightning effects on transmission lines and high voltage insulation.



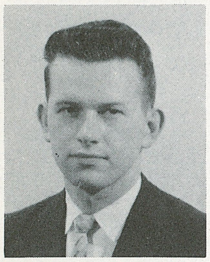
FRANKLIN A. FISHER

Development Engineer - Transient Analysis
High Voltage Laboratory

Joining General Electric in 1951 upon graduation from New Mexico State University as an electrical engineer, Mr. Fisher enrolled on the test program.

During his 2-year test assignment he worked in the Medium Motor, Switchgear, Power Transformer, and Jet Engine components. Subsequent to the test program his career has been devoted to the solution of transmission line problems and power transformer design. Particular emphasis has been placed on investigation of transients derived from lightning and switching surges. Development of high voltage testing techniques and equipment was a consequence of these investigations. A particular contribution was the development of techniques for measuring transients on small scale geometrical models of power transmission lines. His work on geometrical models and actual field investigations of lightning phenomena are reported in AIEE transaction papers.

He is an active member in the AIEE and local societies.



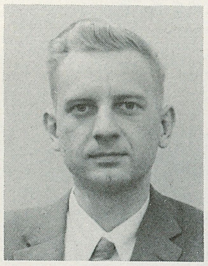
DALE E. HEDMAN

Electric Utility Analytical Engineering

Mr. Hedman joined General Electric in 1959 after receiving BS and MS degrees in electrical engineering from the University of Nebraska. Shortly after coming with the Company he made application and was accepted on the advanced engineering program. This program consists of post graduate level academic work in engineering and includes work assignments in several different product design sections of General Electric.

His activity within the Electric Utility Analytical Engineering component is concerned with utility systems analysis employing the network analyzer facilities.

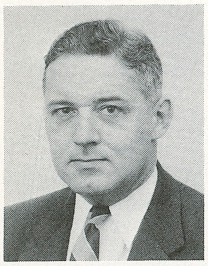
He is an active member of the A. I. E. E. and local technical societies.



DR. M. HARRY HESSE

Application Engineer - Transmission & Distribution
Analytical Engineering
Electric Utility Engineering

Dr. Hesse received a BEE degree from Marquette University in 1951, an MSEE from Illinois Institute of Technology in 1953, and in 1955 a doctorate from Rheinisch Westfalische Technische Hochschule in Aachen, Germany. He has been affiliated with General Electric since 1956, having served as magnetic design engineer in Power Transformer Department before being assigned to his present position. He is a licensed professional engineer in New York State and a member of AIEE and IRE. His membership in honorary societies includes Eta Kappa Nu, Pi Mu Epsilon, and Tau Beta Pi.



I. BIRGER JOHNSON

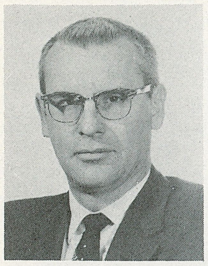
Manager - Transmission & Distribution
Analytical Engineering
Electric Utility Systems Engineering

Mr. Johnson joined General Electric in 1939 after receiving a BSEE and MSEE from the Polytechnic Institute of Brooklyn. Following a year on the Test Course he was assigned to the High Voltage Research Laboratory in Pittsfield, Mass. Since that time his major engineering efforts have been in the field of surge phenomena as they pertain to the analysis, design, and protection of electric utility power systems. He has authored or co-authored some 42 papers on the subject, one of which won first prize in the Power Division of AIEE for 1955-1956.

During World War II he did design and development work in the Distribution Transformer Department and the Aeronautics and Marine Department. In 1945 his activities in surge phenomena were resumed in the Analytical Engineering Section, Central Station Engineering, through studies on systems in miniature on transient network analyzers.

In 1950 he was made manager of Power Systems Engineering, with responsibility for the application and operation of A-C Network Analyzers, Transient Network Analyzers, and D-C Network Analyzers in the analysis of engineering problems. He performs similar duties in his present position.

A Fellow of AIEE, Mr. Johnson has been very active in numerous AIEE committees and working groups. He is a member of CIGRE and of Eta Kappa Nu and Tau Beta Pi honorary fraternities.



ROBERT H. KIMBALL

Application Engineer
Pacific Southwest Region

Upon earning his Bachelor degree in electrical engineering from California Institute of Technology in 1939, Mr. Kimball joined the General Electric Company on its engineering test program. After two years of engineering work in Power Transformer, Switchgear, and Motor Departments, he was assigned to the Los Angeles Office. His experience while in Los Angeles includes installation of heavy electrical apparatus in industrial plants and on board both merchant and naval vessels. For the past 17 years, having completed the Company's Power System Engineering Course, he has directed his efforts toward the application engineering of heavy equipment for selected electric utilities in the Southwest Pacific area.

He is an active member of the American Institute of Electrical Engineers having served on the Executive Committee and as Program Chairman for the Los Angeles Section. During his undergraduate years, he was selected to Tau Beta Phi honorary engineering society.

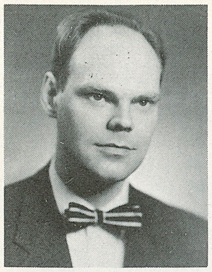
JAMES J. LaFOREST

Development Engineer - Project EHV

Mr. LaForest joined General Electric in 1951, after graduating from Union College with a Bachelor's degree in Electrical Engineering. In 1952 he was transferred to the staff of the High Voltage Laboratory in Pittsfield. In February of 1958 he became a Development Engineer at Project EHV, specializing in the fields of radio noise and corona loss.

Mr. LaForest is active in AIEE activities and is a member of Sigma Xi. He is a licensed professional engineer in New York and Massachusetts.

His work has been described in numerous technical papers.



CARL B. LINDH

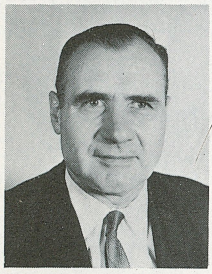
Development Engineer - Project EHV

Mr. Lindh was educated at the Royal Institute of Technology, Stockholm, Sweden, receiving a Master's degree in electrical engineering in 1949.

After a brief stint with the Continental Electric Company in Newark, New Jersey doing generator design work, he joined General Electric Company, Power Transformer Department in 1951. His primary assignment was concerned with cooling developments for power transformers.

In 1955, he returned to Sweden where he had first worked for A. B. Elektromenkano and later for the Swedish State Power Board. In this latter position he was a transformer specialist. While with the Power Board he served in a consulting capacity on transformer problems and represented the Board to the CIGRE transformer working committee. In 1957, he returned to the United States and joined General Electric at Pittsfield. His principal responsibility on the EHV Project at Pittsfield is the analysis of corona losses and the methods of selection of optimum conductors, and he has prepared a computer program to perform this solution.

Accomplishments of his activities are described in five AIEE transaction papers which he co-authored.

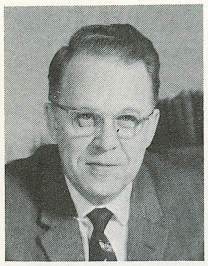


WILLIAM S. MOODY

Manager - Application Engineering
Pacific Southwest Region

Recipient of both a Bachelor and Master's degree in electrical engineering from the University of California, Mr. Moody joined General Electric in 1933. From 1933 to 1936, he participated in the Company's post graduate level advanced engineering courses. His entire career has been devoted to work in the electric utility engineering area -- initially at Schenectady and for the past 25 years in the Los Angeles and Southwest Pacific area. In his capacity he has responsibility for application engineering of all heavy electrical apparatus purchased by the electric utilities within his assigned region.

He is very active in the American Institute of Electrical Engineers having served on the National Relay Committee, Executive Committee, Membership Committee and others. In addition, he has been very active in engineering societies in the Los Angeles area and on several occasions taught technical courses to both General Electric people and electric utility personnel. He is a member of Eta Kappa Nu, Tau Beta Pi, Phi Beta Kappa, and Sigma Xi.



ALBERT F. ROHLFS

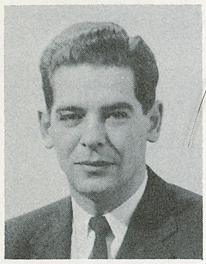
Manager - High Voltage Development
High Voltage Laboratory

Mr. Rohlfs began his career with General Electric in 1937, upon graduation from Bucknell University with a Bachelor of Science degree in electrical engineering.

Upon completion of the engineering test program, he accepted an engineering position in the Transformer plant, at Pittsfield, Massachusetts. His career progressed from that of an engineer performing high voltage developmental testing and transient investigations on transformer windings to various managerial assignments. His present position is concerned with transient analysis development work for power transformers and allied apparatus. This work includes improvements in techniques for measuring high voltage and for detection and measurement of corona. In addition, he has contributed to the understanding of breakdown phenomena in solids, liquids, and gases, and the study of transient voltages including methods for suppression or protection.

He has in recent years authored or co-authored six AIEE transaction papers in the aforementioned fields of interest.

Mr. Rohlfs is an active member of the American Institute of Electrical Engineers.



HARVEY O. SIMMONS, JR.

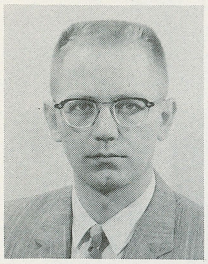
Application Engineer
Power Transmission Engineering
Electric Utility Systems Engineering

Mr. Simmons received a BSEE from Union College and joined General Electric in 1943 on the test program. After engineering assignments in Schenectady and Lynn, he was transferred to headquarters as a proposition engineer, later becoming an application engineer in Distribution Engineering and Systems Application Engineering. He has held his present position as application engineer - Power Transmission Engineering since 1955.

Mr. Simmons is author or co-author of a number of papers dealing with power system stability, kilovar supply, energy transportation economics, conductor size economics, and other related transmission subjects.

In 1962 he attended the HVDC Seminar given by ASEA at Ludvika, Sweden.

He is a licensed professional engineer, a member of Sigma Xi, and is active in AIEE activities.



DELANO D. WILSON

Engineer-in-charge, Transient Network Analyzer
Electric Utility Analytical Engineering

Mr. Wilson received a BSEE from Montana State College, where he held an advanced honor scholarship, and also studied at Great Falls College of Education and Mexico City College. He joined General Electric in 1959 at the Instrument Department and has done design and proposition work on industrial controls and distribution transformers. In 1960 he was assigned to the transient network analyzer and was appointed engineer-in-charge the following year.

A member of AIEE, he has contributed several transaction papers on the subject of switching surges.

JOHN W. YETTER

Senior Engineer - Power Transmission Engineering
Electric Utility Systems Engineering

After receiving an electrical engineering degree from Cornell University and spending a year as a junior distribution engineer with a utility company, Mr. Yetter joined General Electric in 1940 on the Test Program. Two years later he became a design engineer in the Switchgear Division and in 1945 transferred to the Substation Section, Electric Utility Engineering, as an application engineer. In his present position, to which he was appointed in 1955, Mr. Yetter's principal responsibilities consist of application engineering on all phases of a-c energy transmission, and the conduct of economic and technical studies relating to EHV transmission (including membership on the G-E EHV Planning Council).

He is a member of AIEE, serving on the Transformer Committee. He has authored and co-authored numerous technical papers concerned with the design and operation of transmission systems.

SECTION 4

Scheduling of Program

4

Scheduling of Program

The total program schedule is given in chart form in this section. It is an approximate schedule, subject to revision as suggested by conclusions of the initial studies and other requirements that may be apparent as the program progresses.

The initial Switching Surge study has been scheduled for fall of 1962, in order to obtain data enabling Edison to begin the preliminary tower design.

The Lightning Performance study can be made at any time after an initial tower design has been determined. It has been scheduled for early 1963, on the assumption that a functional tower design will be available by that time.

Radio Noise and Economic Conductor studies can run concurrently and can be made at any time. However, since a knowledge of existing radio signal strengths will be helpful in determining the allowable noise levels, and consequently will affect the ultimate conductor choice, these studies have been scheduled in early 1963, to allow time for a signal strength survey, as suggested in Section 1, - D. A soil resistivity survey could run concurrently with the signal strength survey, and provide tower footing resistance data for the Lightning Performance study.

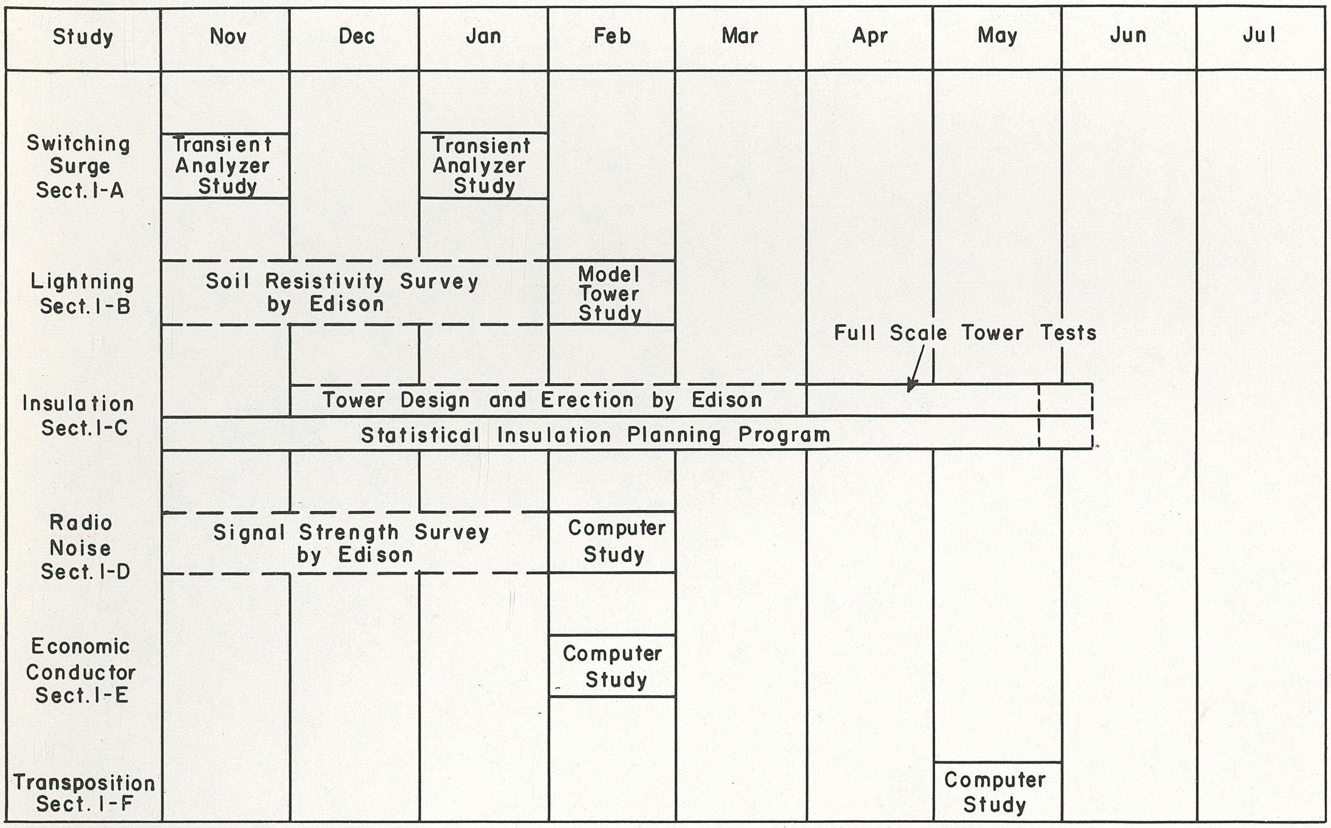
Insulation Planning studies are shown to begin in November 1962 and extend throughout the co-operative program. Initial efforts will frame the assumptions to be used and the scope of application on the Edison 500 kv system. Final stages will consist of computer runs aimed at specific economic decisions. Edison engineers will play a significant role in this activity.

By the spring of 1963, it is expected that a full-scale prototype tower could be designed and erected, followed by approximately two months of testing at intervals interspersed with study of results and determination of tower modifications.

The Conductor Transposition study, which also provides the line electromagnetic and electrostatic parameters, is scheduled for some time after the final conductor configuration is known. Preliminary computer runs will be made as needed, as stated in Section 2, - G.

With the schedule outlined, which includes the writing of reports, completion of the over-all program is estimated for late May or early June, 1963.

SOUTHERN CALIFORNIA EDISON – GENERAL ELECTRIC EHV DESIGN STUDY PROGRAM
APPROXIMATE SCHEDULE



Note: Times shown for specific studies include writing of reports.

Appendix

Upon completion of the studies, complete engineering reports, similar to those written for the Pacific Gas & Electric studies, will be written. In some cases, preliminary conclusions will have to be drawn in order to continue with related studies. For example, an initial transient analyzer study will be made to determine the approximate switching surge ratio for use in preliminary tower design. In these cases, both preliminary and final reports will be written. Copies will be provided to Southern California Edison in the amount requested.

Conclusions and recommendations will be drawn in accordance with the Edison Scope of Work document, as follows:

Conclusion and/or Recommendation	Obtained from
Design Criteria: Maximum design operating voltage Switching surge ratio Arrester location Insulation levels Line switching (breaker location) Compensation, its rating, location, and switching Line and transformer bank relaying Possible operating limitations	Switching Surge Study Insulation Study (Statistical Insulation Planning)
Anticipated lightning outage rates vs. annual costs of methods of outage reduction	Lightning Performance Study
Conductor size and configuration	Economic Conductor Study Radio Noise Study Insulation Study
Evaluation of structure designs	Switching Surge Study Lightning Study Insulation Study (Full-scale tower tests) Comparative tower cost data
Line constants and transposition	Conductor Transposition Study
Equipment Recommendations: Basic insulation levels, 1 Ø vs. 3 Ø transformers, tertiary windings, LTC, reactors (HV or LV), arrester performance requirements, 2-step switching, etc.	Switching Surge Study Insulation Study Product Departments Power Transformer High Voltage Switchgear Insulator Capacitor Communication Products
Testing: Full-scale tower testing conclusions	Insulation Study